Impact of Electric Vehicles on Day-ahead Prices in France

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Seminar Chaire FDD 10 June 2011

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Acknowledgements

Joint project between the Cerna & the Cenerg

- Jérome Adnot (Cenerg)
- Philippe Rivière (Cenerg)
- Valeriia Iezhova (internship on wind power)
- Amira Iguer (internship on electric vehicles)
- Alain Galli (Cerna)

Many thanks to EpexSpot (formerly Powernext) for providing access to historic data on the aggregated offers to buy/ sell electricity in France, and especially to Audrey Mahuet.

Changing context

Over next 15 years (2025), the French government plans

- **introduction of 4 million electric vehicles (EV)**
- **introduction of smart meters to all households**
- **introduction of wind power**
- **most of nuclear power plants will reach 40 year age & will require more maintenance. Some may be decommissioned**
- **2 new nuclear reactors will be brought into service**
- **several new gas powered turbines are being built**

What effect will these changes have on day-ahead prices?

Factors not considered

Factors which are outside the scope of the study but which will affect electricity prices in the future are:

- **The Central Western Europe market coupling (which started in Nov 2010)**
- **The *Loi Nome*, a new French law which has been voted but not yet brought into effect.**
- **Stochastic nature of wind power**
- **New capacity market in France**
- **Decommissioning of nuclear power plants in Germany**

Because of insufficient data at present.

Objectives

We aim to study the effect of the introduction of EVs & of the changing generation fleet on electricity prices on week days by simulating prices 24 hours per day for the next 10 years.

We are not attempting to predict prices on particular dates. Instead we want the histograms of prices to be realistic, that is, with realistic peaks & troughs (not just estimates of the average price) because the peaks provide the price signal for building peaking plants.

Which method to use?

Overview

Papers on the impact of wind power and/or electric vehicles on day ahead prices make two assumptions:

- the supply curve equals the full merit order
- demand is inelastic

While this approach correctly identifies the marginal producer (& hence price) in normal times, it does not produce the price peaks seen in practice during periods of stress. Usual explanation for this is the exercise of market power.

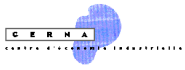
These assumptions are too simplistic.

Overview

The classic approach is appropriate in the case of a pool. But in practice:

- **Most electricity is traded via futures & forwards, or is produced in vertically integrated utilities**
- **Only a small part of electricity is traded on day-ahead market. Much of it represents adjusts to longterm positions as function of new info.**

Finally bids for the day-ahead auction close at a fixed time.



Overview

After reviewing literature talk is split into two parts

- **In-depth analysis of the sequence of events in one particular period of stress, which shows that neither of assumptions was true**
- **Proposal for a new method for simulating prices based on the observed offers to buy/sell power.**

Overview

- Review of literature
- Understanding how price spikes occur
- Our method for simulating prices
- Scenarios considered:
  - 2 for recharging EVs
  - 2 for generation fleet
- Results
- Conclusions

State of art

Jensen & Skytte (2003) first suggested that because of low marginal cost, wind power might cause a drop in day-ahead electricity prices

Focus on Europe

As de Miera et al (2008) provide thorough literature review, we focus on that paper & recent work notably empirical studies:

- Weigt (2009)
- Sensfuss et al (2008)
- Pfluger et al (2009)

Literature

de Miera et al (2008)

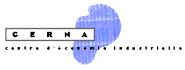
Worked on impact of wind power on wholesale prices in Spain

Identified two effects

a) Direct effect where wind power displaces conventional thermal power in merit order.
b) Indirect effect due to reduction in CO2 emissions. Ignored this

Difficulties encountered

a) Wind varies rapidly over short periods of time
b) Interaction between wind & hydro power
c) Lack of detailed information on plant availability, thermal performance etc

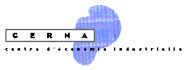


Literature

de Miera et al (2008)

Assumptions

- Electricity demand is totally inelastic
- Ignored restrictions on ramp up/down, & on number of stops/starts per year
- Used actual equipment availability
- Used actual hydro plants that were dispatched
- Used actual imports/exports



Literature

de Miera et al (2008)

Information used

- Spanish TSO provides data on installed capacity of thermal plants, thermal production, wind production, & monthly figures on availability of thermal plants.
- NBP Gas prices
- CO_2 prices from EEX (Germany)

Authors compared

- Actual electricity prices from OMEL (ie with wind)
- Simulated prices for case without wind power

Conclusions: Wind power led to a reduction of about

- 7 € /MWh in 2005
- 5 €/MWh in 2006, &
- 12 €/MWh in first half of 2007

Literature

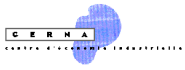
Weigt (2009)

- Analysed extent to which wind power could replace conventional thermal power in Germany using hourly wind feed-in data over period 2006-mid 2008
- Concluded: there had been a load shift of 4-5 GW, & hence reductions of about
  - 10 €/MWh in 2006
  - 17 €/MWh in 2007
  - 19 €/MWh in first half of 2008
- Study was only possible because 4 German TSOs started releasing hourly wind feed-in data.

Literature

Sensfuss et al (2008)

- Used agent-based simulation approach to evaluate impact of wind power on merit order in Germany over the period 2001 – 2006.
- Used PowerAce model in which merit order is based on variable marginal costs which in turn depend primarily on fuel costs;
- Modelled Day-ahead market, CO_2 market & different reserves managed by grid-operator.
- Incorporated « traders » designed to replicate strategies used in practice;



Literature

Sensfuss et al (2008)

- Simulated random outages of power plants
- Ran 50 simulations first with wind power & then without it, then averaged prices in order to smooth variations due to random outages.
- Conclusions: wind power led to a drop in market prices in Germany of 7.8 €/MWh in 2006

Literature

Authors	Country	2005	2006	2007	2008
Saenz de Miera et al (2008)	Spain	7 €/MWh	5 €/MWh	12 €/MWh (1st half)	
Weigt (2009)	Germany		10 €/MWh	17 €/MWh	19 €/MWh (1st half)
Sensfuss et al (2009)	Germany		7.8 €/MWh		

Literature

Some differences between papers are due to different information which is available in each country.

Common features of these papers are

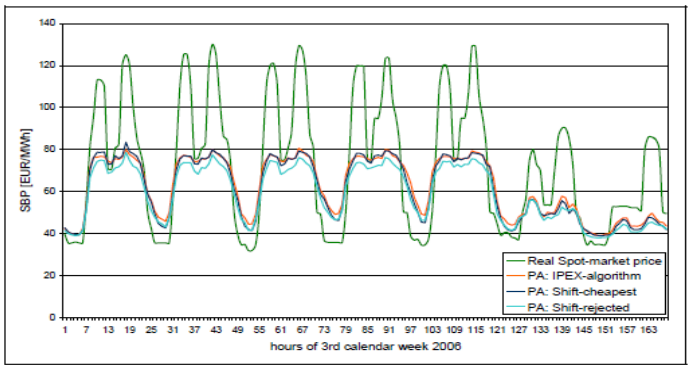
- Demand is assumed to be inelastic
- Electricity price is computed using merit order for system, that is, assuming that all electricity is traded via day-ahead electricity auctions. In fact most is sold in bilateral OTC trades.

Literature

Pfluger et al (2009)

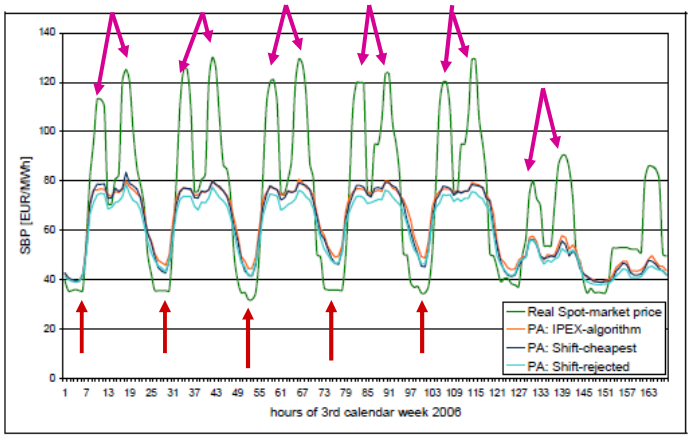
- Used same methodology (& PowerAce model) to study effect of solar power generated in Africa on the Italian market.
- Authors compared simulated prices with observed ones
- Agreement is good in off-peak periods
- But model seriously under-estimates prices in peak periods & over-estimates them in early morning (1am – 5am)

Pfluger et al (2009)

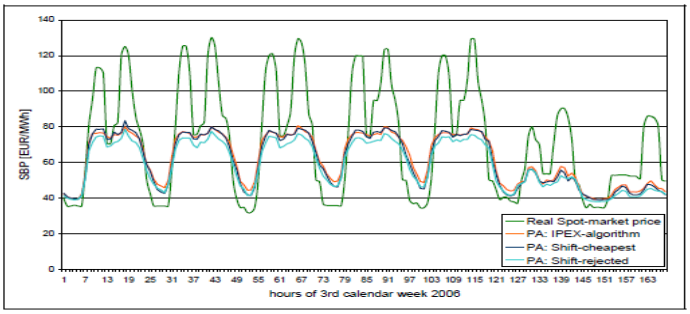


Good agreement part of day: so it is correctly identifying the marginal type of power plant.

Pfluger et al (2009)



What is causing the discrepancies?



According to the authors, the peaks are evidence of the exercise of market power.

But we are not convinced that this is true.
Other factors may be at work.

Literature

Possible reasons for mis-estimation

1. **Fact that the authors averaged prices from 50 simulation runs.**
2. **As Sensfuss et al (2008) noted, most electricity is traded OTC & not via the electricity bourse. In our opinion, the offers to sell power on bourse are not just a scaled down version of the overall merit order.**

So we need to be able to generate/simulate realistic curves of aggregated offers to buy/sell electricity in order to get realistic prices.

Literature

Possible reasons for mis-estimation

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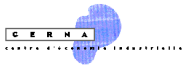
So we need to be able to generate/simulate realistic curves of aggregated offers to buy/sell electricity in order to get realistic prices.

Our aim

By studying publically available data on the aggregate offers to buy & sell electricity on French market, we will show that these two assumptions are unrealistic:

- **Demand on the bourse is elastic**
- **Supply varies rapidly from one time of day to next & from one day to next. It is not just a scaled down version of the merit order for the whole system.**

We propose a method for generating aggregate offers in the future based on the offers observed in a typical year (Oct 2007 to Sept 2008).



Overview

- **Review of literature**
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- **Our method for simulating prices**
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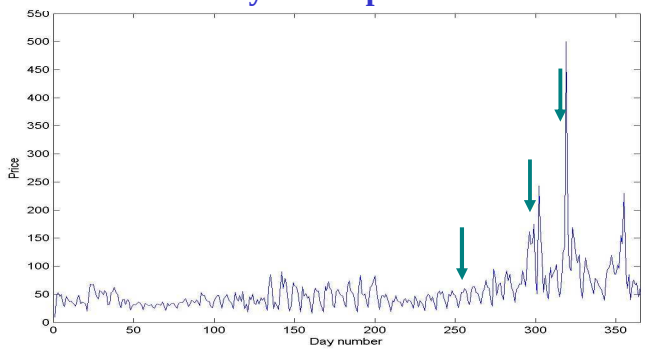
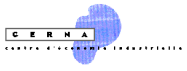
- **Results**
- **Conclusions**

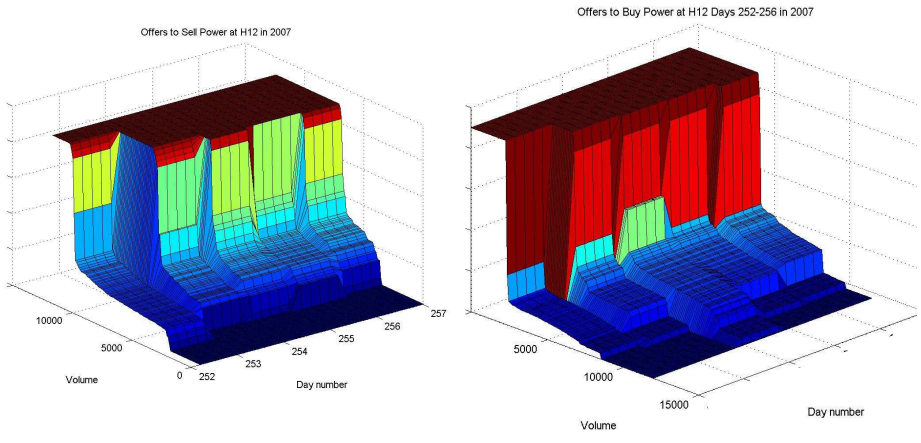
Offers to sell

Powernext Day-ahead prices H12 in 2007



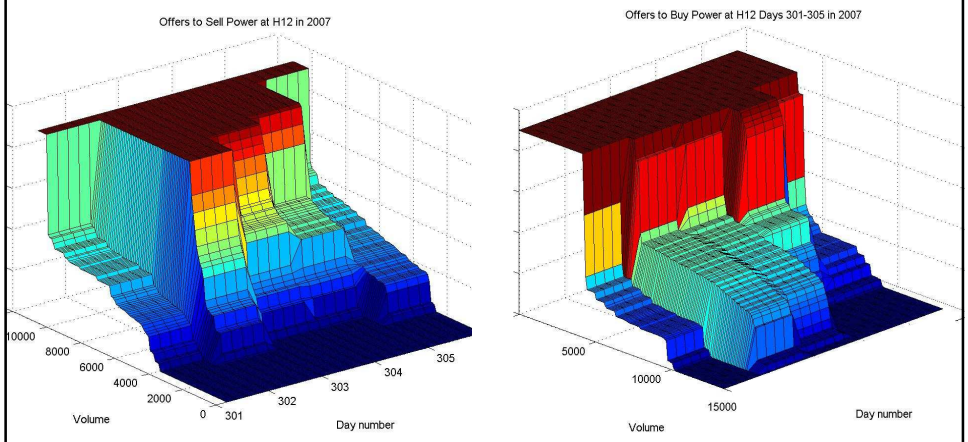
How variable were offers to sell power H12 in 2007?





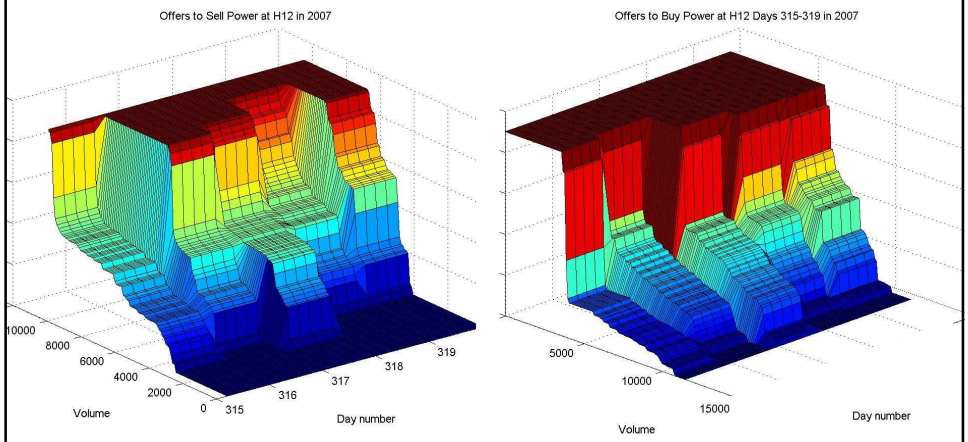
H12 on Days 252 – 256 (August) in 2007

Offers to buy & sell



H12 on Days 301-305 in 2007

Offers to buy & sell

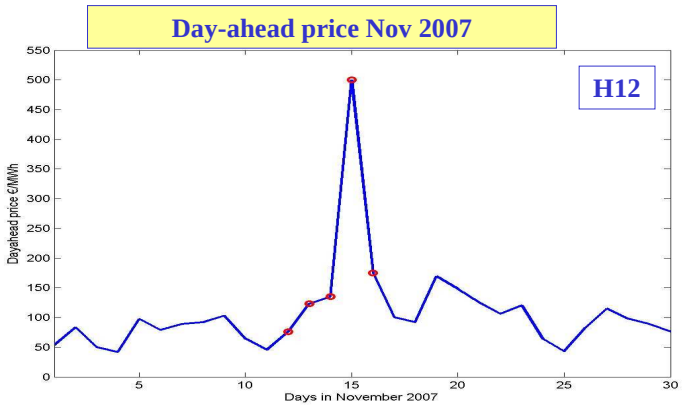


H12 on Days 315-319 in 2007

Offers to buy & sell

- The offers to buy power are elastic
- The offers to sell vary markedly from one day to the next.

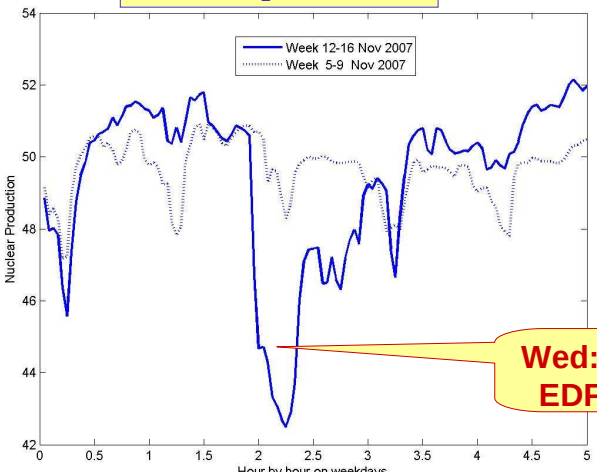
Understanding how price spikes form



Price rose very high on Thurs 15, then dropped on Fri 16.

Understanding how price spikes form

Nuclear production

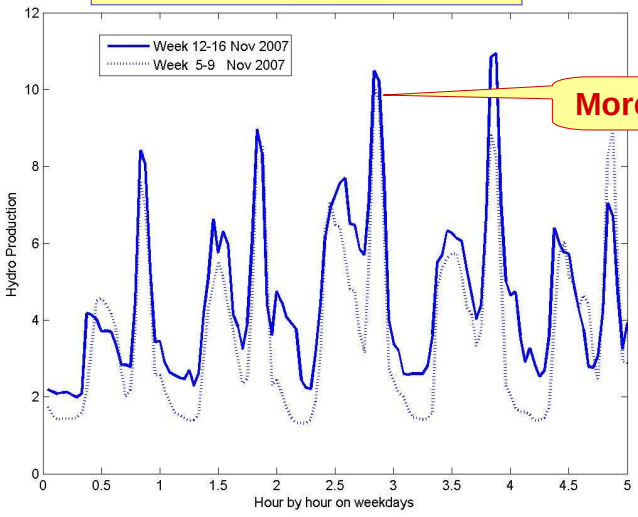


Wed: 18% drop!
EDF on strike

Hour by hour over 5 days

Understanding how price spikes form

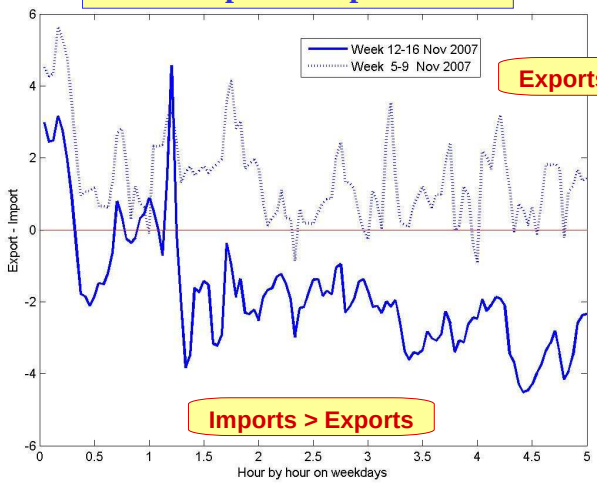
Hydro production in France



More hydro

Understanding how price spikes form

Export - Import

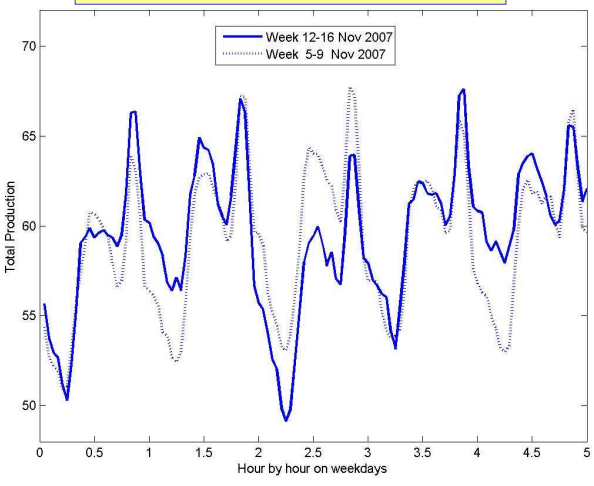


Exports > Imports

Imports > Exports

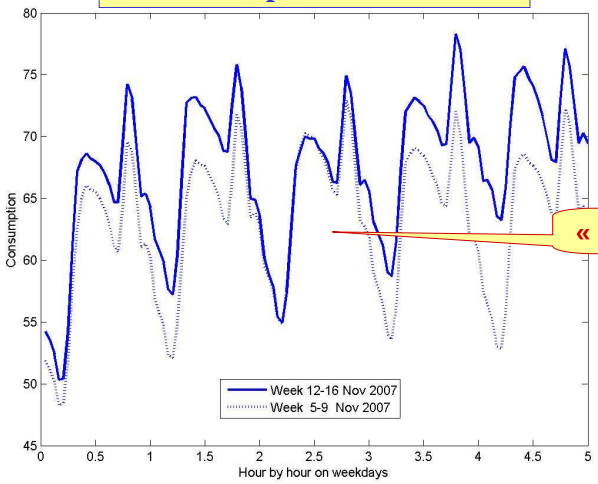
Understanding how price spikes form

Total production in France



Understanding how price spikes form

Consumption in France



Understanding how price spikes form

The loss of production on Wednesday from nuclear plants was compensated on system as a whole

- **Reducing the consumption: « effacement »**
- **More hydro-electricity**
- **Imports from neighbouring countries**

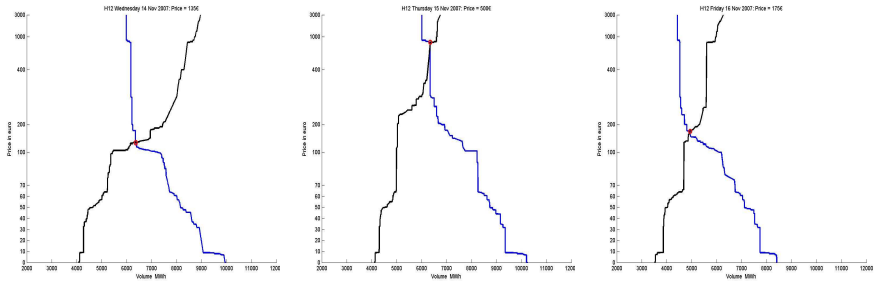
But the price spike occurred on THURSDAY. Why?

Because offers to buy/sell for Thursday had to be submitted to the bourse before noon on Wednesday (when nuclear production was dropping rapidly).

Understanding how price spikes form

How events affect offers to buy/sell power

Wednesday | **Thursday** | **Friday**



Understanding how price spikes form

Day-ahead market

Offers to buy/sell electricity can vary from one day to next in reaction to events.

When the events are predictable (cold weather) price spike occurs on same day as event. When they are not predictable (EDF strike) price spike occurs the following day.

That is, offers to buy/sell are not a scaled-down version of full merit order on that day.

Understanding how price spikes form

Our conclusions

The aggregate curves can change dramatically from one day to next.

The aggregate curve of offers to buy power is not inelastic.

The aggregate curve of offers to sell electricity is not a scaled-down version of the merit order. It reflects how much spare capacity French utilities have & whether foreign utilities are exporting to/importing from France.

It would be difficult to generate realistic pairs of aggregate curves unless one bases them on existing curves.

Overview

- **Review of literature**
- **Data on electric system available to public**
- **Understanding how price spikes occur**
- **Our method for simulating prices**
- **Scenarios considered:**
  - **2 for recharging EVs**
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- **Results**
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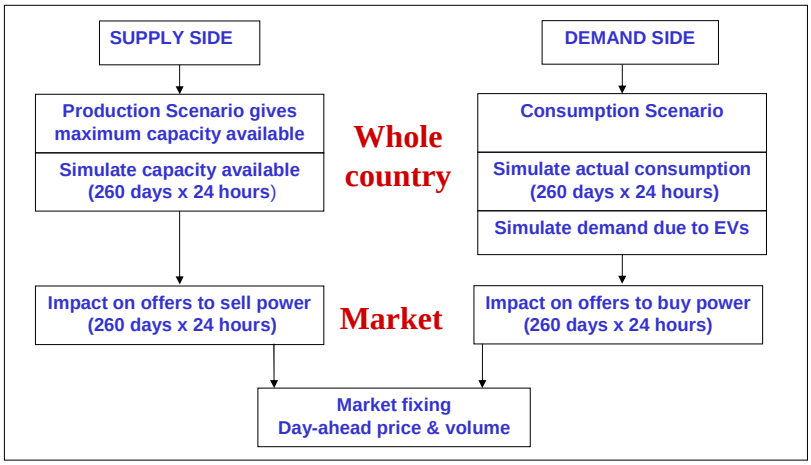
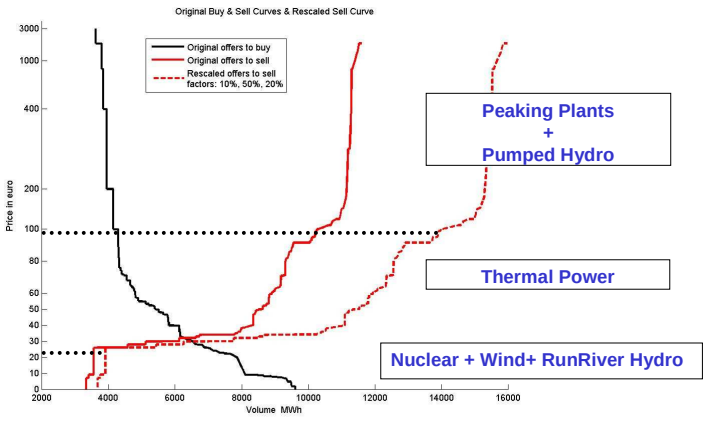
Our method



Our method: supply side

Rescaling offers to sell power



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Scenarios for recharging EV batteries

Two scenarios were considered

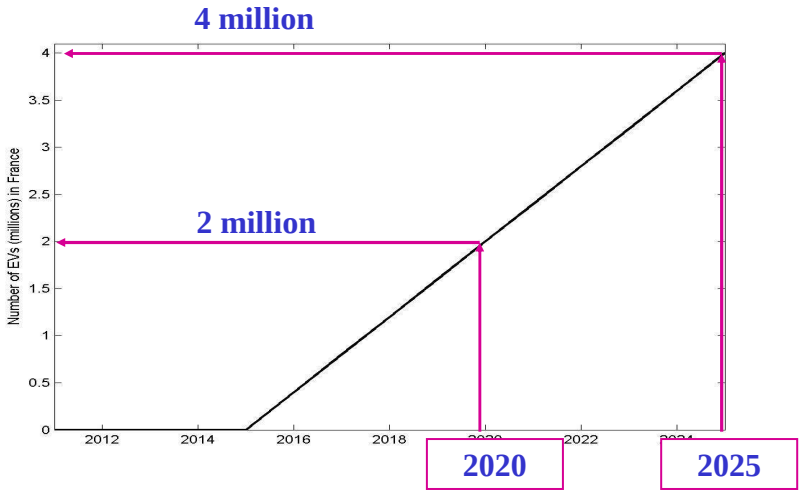
- EV scenario N° 1: without V2G
- EV scenario N° 2: with V2G

Scenario N° 1: batteries are recharged at rate 2.5 kWh from 9 pm until 6am.

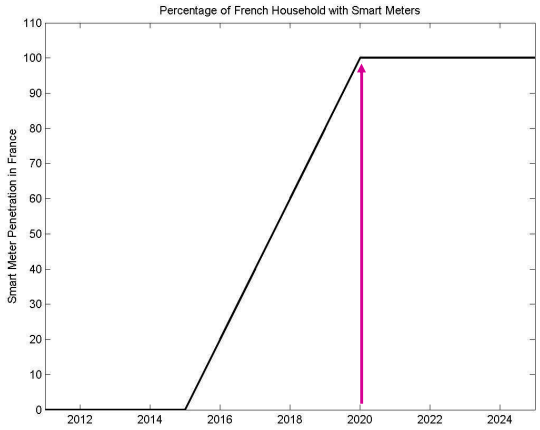
Scenario N° 2: batteries are recharged at rate 3.2 kWh from 9 pm until 6am. Power is drawn down from batteries from 8am till 3pm

We did not consider Doomsday scenarios where EVs are recharged during evening peak period.

Number of EVs in service



Percentage of houses with smart meters



Scenarios for generation fleet

Current generation fleet:

- 75% nuclear
- 13% hydro
- 10% fossil-fuel thermal
- 2% other renewables

Government plans for the future		
	2006	2020
Onshore wind	1,600 MW	19,000 MW
Offshore wind	0	1,400 MW
Solar	0	5,400 MW

Scenarios for generation fleet

Optimistic scenario (HHH) vs pessimistic scenario (LLL)

2 scenarios for wind power: High, Low

3 scenarios for nuclear: High, Medium, Low

2 scenarios for fossil fuel: High, Low

Little perspective for additional hydro power

http://clients.rte-france.com/

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Results of simulations

Ran 50 simulations, each 24 hours x 260 weekdays in 2020:

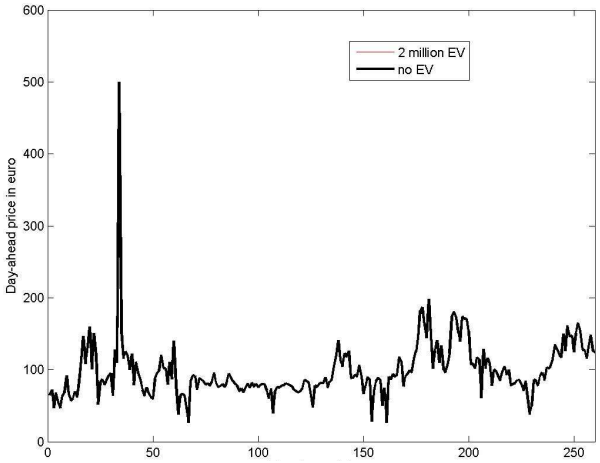
- **EV scenario N° 1: without V2G**
- **EV scenario N° 2: with V2G**

For most optimistic (HHH) & most pessimistic (LLL) generation fleet scenarios.

For comparison purposes we present 1 simulation of each at H5 (early morning) & at H12 (midday peak). In each case the red curve corresponds to 2 million EV, the black line corresponds to no EV.

Peak period, without V2G

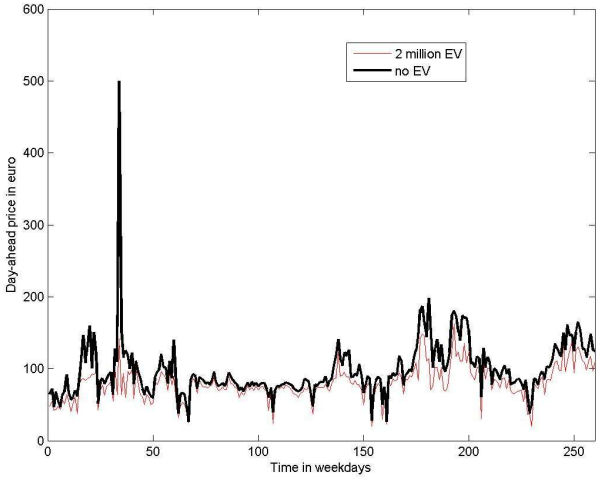
Simulated prices H12 in 2020



Time in weekdays

Peak period, with V2G

Simulated prices H12 in 2020



Time in weekdays

Results of simulations

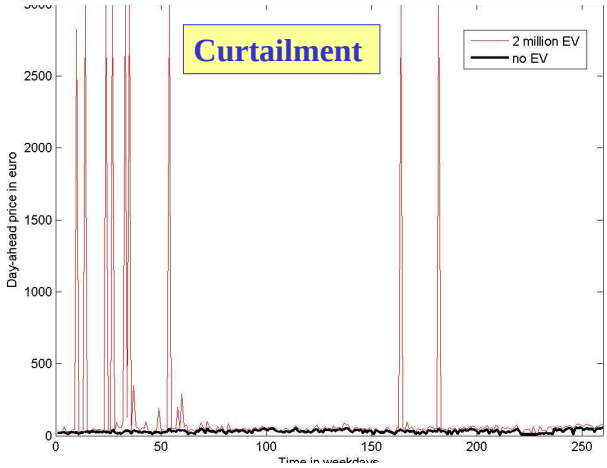
During peak hours, power is drawn from batteries in scenario 2 (with V2G) but not in scenario 1.

In V2G case, the more EV there are, the lower the prices.

In other case, the prices are the same irrespective of number of vehicles (hence only one curve).

OffPeak period, without V2G

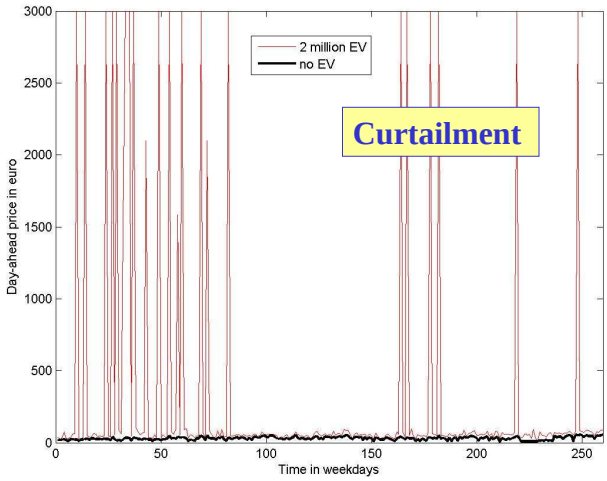
Simulated prices H5 in 2020



Time in weekdays

OffPeak period, with V2G

Simulated prices H5 in 2020



Time in weekdays

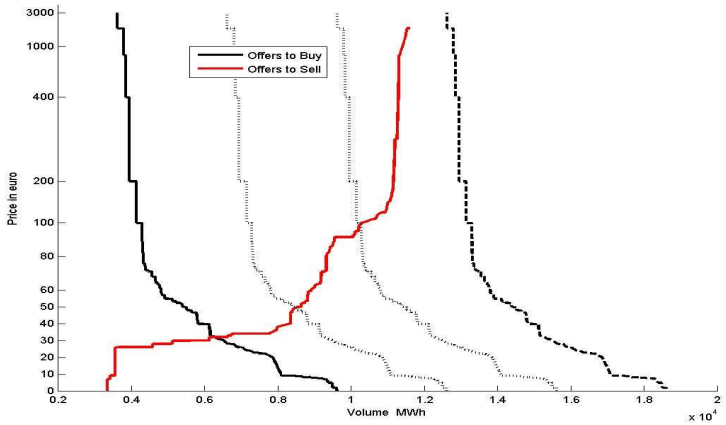
Results of simulations

During offpeak hours, batteries are charged in both scenarios but more power is needed in scenario 2 (with V2G) than in scenario 1.

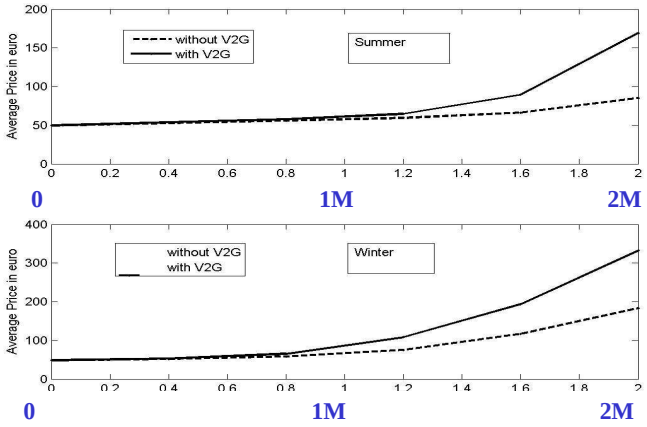
So the more EV there are, the HIGHER the prices are.

There are lots of peaks (& curtailment) in both cases, but there are far more in the V2G case.

Curtailment

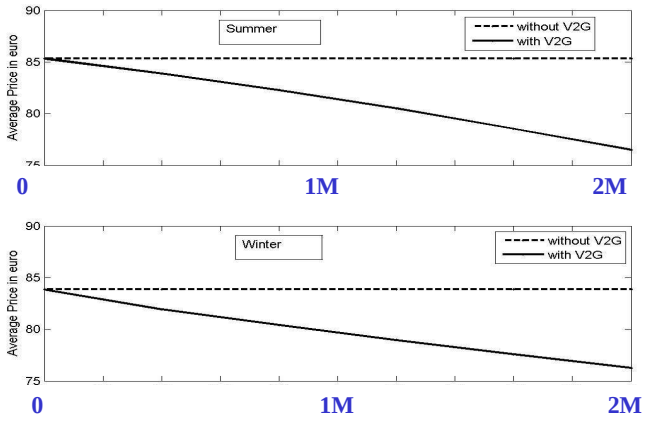


Average offpeak price



Number of EVs in service

Average Peak price



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Conclusions

The primary objective was to develop a method for simulating day-ahead prices in the future based on the aggregated offers to buy & sell power in France rather than by assuming that (1) offers to sell reflect the overall merit order and (2) demand is inelastic.

This has been achieved.

Conclusions

The results obtained to date are based on the data from the reference year Oct 2007-Sept 2008 (as this was the last typical year available when the project started).

Extrapolating these patterns forward suggests that

- day-ahead prices would drop in peak hours in the V2G option.
- day-ahead prices would rise sharply in offpeak periods with both options for recharging batteries, if large numbers of EVs come into service.
- planned increases in generation fleet are not sufficient to cover the increased demand in offpeak periods, leading to frequent cases of market curtailment.

Conclusions

The results obtained to date were based on the data from the reference year Oct 2007 – Sept 2008 (as this was the last typical year available when the project started).

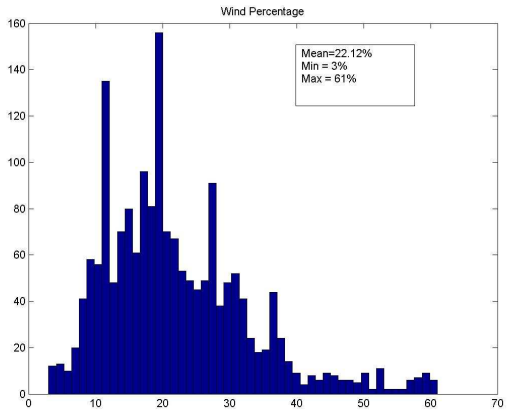
Two limitations of the work are

1. It does not take account of the coupling of the French & German markets (Nov 2010).
2. The erratic nature of wind availability

The work will be repeated early in 2012 when there will be a full year of data from the joint French & German market.

Conclusions

Wind availability data became public in France in Jan 2011. It is much more erratic than we had expected.



Conclusions

A more fundamental limitations of the work is that it does not take account of the fact that utilities will change their strategy as more wind power & more EVs are introduced.

As far more power will be required in offpeak periods to recharge the batteries of EVs, power plants that are currently offline at night will run.

Alternatively, if huge quantities of wind power become available this will be used at night to recharge EVs as is planned in Denmark & NZ

Modelling changes in behaviour will be more challenging

Any questions?

Information available on electric system

From grid operator RTE

- Electricity consumption in France 24 hours per day 365 days per year from 1996 onwards.
- Production of electricity in France 24 hours per day 365 days per year from Nov 2006 onward:
  - total production
  - nuclear production
  - gas turbines
  - hydro (run of river + dam-based)
  - coal-fired
  - diesel & peaking plants
- Capacity available each day for same classes as above but with run-of-river separate from dam-based, from Nov 2006 onward.

Source: http://clients.rte-france.com/

Information available on electric system

From grid operator RTE

- Quantities of electricity exported & imported 24 hours per day 365 days per year from Nov 2006 onward:
  - Total quantity (Export – Import)
  - Total exported
  - Total imported
  - Net balance from following countries: Germany, UK, Belgium, Italy, Spain & Switzerland
- Observed production from wind turbines 24 hours per day 365 days per year from Jan 2010 onward.

Very little data was available before Nov 2006.

Information available on electric system

The fact that most data is only available from Nov 2006 onward complicated our study.

As we started in March 2010, only 2 full years were available.

Electricity consumption dropped in Q4 2008 because of economic crisis, so the year Oct 2008 – Sept 2009 is atypical.

So we based our study on year from Oct 2007 to Sept 2008.

Information available on electric system

RTE : Multi-Year Forecasts
Bilan prévisionnel

By law RTE is required to produce reports on the state of the electric system every 2 or 3 years. It must estimate the prob that there are more than 3 hours when demand cannot be satisfied for the next 10-15 years into the future.

If this is too high it recommends the construction of additional power plants, & specifies whether these should be base-load, semi-peak or peaking plants.

Source: http://www.rte-france.com/fr/actualites-dossiers/a-la-une/bilan-previsionnel-actualisation-2010-la-securite-electrique-de-la-france-devrait-etre-assuree-jusqu-en-2013

Information available on electric system

RTE: Multi-Year Forecasts

To do this it has developed a protocole for simulating the French electric system which is very sensitive to temperature.

RTE has constructed 500 1-year weather patterns in order to simulate the hourly demand.

The hourly supply is also simulated based on a detailed knowledge of the generation fleet, and the marginal costs.

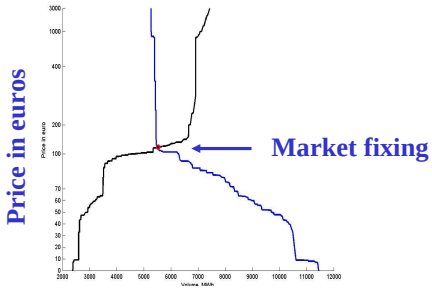
RTE tests whether the supply satisfies the demand.

Source: http://www.rte-france.com/fr/actualites-dossiers/a-la-une/bilan-previsionnel-actualisation-2010-la-securite-electrique-de-la-france-devrait-etre-assuree-jusqu-en-2013

Information available on electric system

Information from EpexSpot

EpexSpot (formerly Powernext) is the electricity bourse in France. In addition to the market fixing prices & volumes, it provides the aggregated offers to buy & sell power.



Source: www.epexspot.com